Re-evaluating the sensitivity of habitats to climate change

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Foreword

The impact of climate change on the natural environment is becoming increasingly evident, and the scale and extent are projected to increase. From observed impacts, it is clear that not all habitats are the same in terms of their sensitivity to a changing climate. Some, such as lowland calcareous grassland, appear to be relatively resilient, whilst others such as montane habitats are more sensitive.

To build the resilience of the natural environment interventions will need to focus on those elements that are most sensitive and therefore likely to be adversely affected. In this context, consideration of the differential impact of climate change on habitats is important if we are to protect our remaining natural environment and minimise biodiversity loss.

This report presents the results of an expert led assessment that refines our understanding of the sensitivity of habitats to climate change. Using the Delphi technique and a panel of academic and practitioner experts, an externally validated 5-point scale of sensitivity was developed for habitats in good and degraded condition.

The assessment will guide the prioritisation of interventions to those habitats most sensitive to climate change and thus support efforts to reduce climate risk and support nature recovery.

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Executive summary

Introduction

The climate of the UK has warmed significantly since the pre-industrial period. The Met Office UKCP18 climate projections highlight continued warming of all areas, warmer summers and wetter winters, decreased summer precipitation but an increase in the winter with increased intensity and frequency. There is also a projected rise in storm events and sea levels will continue to increase. Climate change, coupled with other existing pressures, such as pollution, land-use change, and agricultural intensification poses serious risks to many UK habitats and the species within them.

Habitats provide numerous ecosystem services (regulating, provisioning, supporting, cultural) to flora, fauna and humans. We therefore need to better understand habitat sensitivity to projected climate changes. This will help enable and target appropriate adaption and support to species, habitats and ecosystems to thrive with the inevitable alterations climate change will cause.

Aims and Approach

This project was funded by Natural England and delivered in partnership with the Countryside and Community Research Institute (CCRI). The research aimed to come to an expert-led consensus of the sensitivity of UK habitats to climate change.

Specific aims of this project were:

- Provide an up to date and rigorous assessment of UK habitat sensitivity to climate change
- Produce a 5-point scale of sensitivity for pristine and degraded habitats
- Identify areas of uncertainty in our knowledge of habitat sensitivity to climate change pressures

Produce an assessment that will be used to support the prioritisation of interventions to promote adaptation to climate change.

The Delphi approach was used to collect and collate expert views on the sensitivity of habitats to climate change. Delphi is a social science technique used to collate a range of opinions from selected participants on a given question or topic. This method was chosen as it can accurately capture a range of opinions, evidence underpinning these opinions and allow participants to come to a consensus view. In this case, how sensitive each habitat is to climate change projections. The criteria for the scoring was to consider each habitat in relation to projected climate change over the next 30 years outlined in the Met Office UKCP18 report and place a mark on the 5-point scale accordingly.

The 22 experts were selected based on their knowledge of specific habitat types and/or climate change. The panel consisted of experts from practitioner and academic organisations, both governmental and NGOs. A 1-5 scale (1 low, 5 high) provides a more detailed view of habitat sensitivity than the current 3-point scale. It allows differentiation to be drawn between low and low-medium, medium and medium-high to very high which can potentially be incorporated into vulnerability modelling.

Experts were asked to score habitats in good condition and the same set of habitats in a degraded condition to allow for comparison. These responses were collated, averaged and sent back to the same set of experts to review. Alterations and comments on the scores could then be made before the final scores were collected. The project focused on terrestrial, freshwater and coastal (excluding marine) JNCC UK BAP Priority Habitats (Joint Nature Conservation Committee UK Biodiversity Action Plan Priority Habitat Descriptions) and EUNIS (European Nature Information System Habitat Descriptions) habitats.

Results

Almost all habitats were ranked medium to highly sensitive, apart from arable field margins which were low (1) in both good and degraded condition. This indicates that UK habitats are very sensitive and changes to these habitats will occur under climate projections. Habitats ranked at high (4 and 5) sensitivity in both a good and degraded condition and therefore the **most sensitive** are:

- Most river habitats and standing water bodies (lakes and ponds)
- Lowland beech and yew woodlands, wet woodlands and native pine woodlands
- Wet lowland meadows
- Coastal grazing marsh
- Wet and dry lowland heath
- Fen, marsh and swamp
- Mountain heath and willow scrub
- Coastal (machair, saltmarshes, mudflats, saline lagoons)

Several habitats had a large difference in sensitivity scores between degraded and good condition, highlighting that degradation has an important influence on sensitivity. These habitats are:

- Bog habitats: 3 in good condition, 5 when degraded.
- Some woodlands: 2-3 in good condition, 4 when degraded.
- Inland rock and scree habitats: 1 in good condition, 3 when degraded.
- Coastal sand dunes: 3 in good condition, 5 when degraded.

Climate related pressures identified by experts that increase habitat sensitivity include sea-level rise, lack of space, temperature stress, drought, eutrophication, increased storms and invasive species. Our findings align with the results presented in the CCRA Natural Environment Assets Technical Report, further solidifying that the habitats identified as highly sensitive are most vulnerable.

Key findings and Next steps

- The majority of habitats were assessed as being at medium (2-3) or high (4-5) sensitivity to climate change irrespective of whether in good or degraded condition, suggesting that change is inevitable.
- In general habitats in a degraded condition were assessed as being more sensitive to climate change than habitats in good condition.
- Large differences in the sensitivity of good compared to degraded habitats were recorded where the source of degradation directly interacted with climate impacts. For example, compromised hydrology in wetlands and coastal squeeze affecting coastal habitats.
- Priority should be given to habitats with the highest sensitivity as this will translate to higher risk. These include montane, freshwater and wetland habitat in good condition and coastal habitat compromised by coastal squeeze.
- Intervention should aim to address the causes of degradation that lead to increased climate sensitivity through appropriate protection and restoration.
- Habitat creation should focus on those habitats with high sensitivity to compensate for potential climate driven loss or degradation.
- All habitats will show increasing levels of change from historic baselines due to climate change. Consideration of “what good looks like” under this trajectory of change will be required to help prioritise interventions and determine their effectiveness.

Contents

Background and project aim

1.1 Background and context.

The climate of the UK has warmed significantly since the pre-industrial period. Over the last 30-years the average temperature has been 0.9°C warmer than the preceding 30 years (Met Office 2021). All the top ten warmest years for the UK, in the series from 1884, have occurred since 2002 (Met Office 2022). The UKCP18 climate projections highlight continued warming of all areas, warmer summers and wetter winters, decreased summer precipitation but an increase in the winter with increased intensity and frequency. There is also a projected rise in storm events and sea levels will continue to increase.

Climate change is having ever greater impacts on natural ecosystems (Renwick *et al*. 2012, Pörtner *et al.* 2021); and this will continue as climate change intensifies (IPCC 2022; Carbon Brief 2021). Climate change and biodiversity loss are now widely accepted as environmental emergencies (Mori 2020) requiring immediate and focused responses. In this context, consideration of the differential impact of climate change on habitats, and thus the threat that climate change poses to them is important. This understanding will help prioritise our interventions to protect our remaining natural environment, minimise biodiversity loss and maximise resilience to environmental changes including climate change.

It is clear, that not all habitats are the same in terms of their sensitivity to a changing climate (Malhi et al. 2020; Mousley & Van Vliet 2021). Some, such as lowland calcareous grassland, appear to be relatively resilient (Grime et al. 2008), whilst others such as montane habitats (Trivedi et al. 2008) are more sensitive to a changing climate, in this case warming.

1.2 Current approach.

Natural England's understanding of these issues was first articulated in the England Biodiversity strategy, (Mitchell *et al*. 2007), which grouped habitats on a three-point scale of; High, Medium or Low sensitivity. This hierarchy has been used in NE's climate change vulnerability modelling (Taylor *et al*. 2014) and NE's broader approach to understanding risk and adaptation (Natural England and RSPB 2019). The vulnerability model offers one way to operationalise this understanding, but the High-Medium-Low hierarchy and limited number of habitats considered limits the resolution that researchers and policy makers are able to work with. For this reason, preliminary work was recently undertaken by NE specialists to expand the scale into a 1-5 score and include more habitats (Atkins 2018). In addition, enhancing the granularity of the assessment of priority habitat sensitivity to climate change will make relative comparison of habitat types easier, will allow greater spatial targeting such as for agri-environmental schemes and will facilitate prioritisation of habitats both individually, but maybe more importantly at landscape scale to focused interventions.

1.3 Aim of the project.

To allow a more nuanced understanding of the threat posed by climate change and to facilitate the prioritisation of habitat protection needs, **this project's aim was to produce a rigorous and expert assessment of the sensitivity of habitats in England to climate change on a 5-point scale**. The objective was to incorporate the latest evidence and expert opinion into a 5-point scale on the sensitivity of habitats to climate change. In addition to this, the degree of habitat degradation (good or degraded) was considered when assessing the sensitivity of habitats to climate change. A **good habitat** was defined as one where it contains all or most of the key organisms expected in that habitat type and where it is functioning similarly or close to a pristine habitat, and therefore can be considered to be in a favourable condition or conservation status. A **degraded habitat** was defined as one which is still recognisable as of that habitat type but is lacking some key element/species/ association. The aim was to understand how the status of the habitat might impact its sensitivity to climate change. Broadly speaking a degraded habitat is likely to be more adversely impacted than a habitat in good condition (Malhi et al 2020), primarily because of a loss of resistance and resilience to environmental perturbations.

The sensitivity of a habitat to climate change is the outcome of the inherent sensitivity and adaptive capacity of the habitat to environmental changes. The impact of the level of degradation on the sensitivity to external perturbations varies across habitats. For example, a hydrologically intact functioning lowland raised bog would be relatively resilient to climate change, whilst one where the hydrology is compromised would likely to be highly sensitive; conversely the sensitivity of calcareous grassland would be less likely to change as significantly whether it is in good condition or not (depending on the outcome measure assessed) (Fig 1). The reason being that “degradation” of calcareous grassland in many cases results from factors such as agricultural improvement, inappropriate grazing or scrub encroachment that have less of an interaction with climate change.

In the UK, most habitats are degraded to some extent, for example less than 40% of SSSIs are in favourable condition (UK Government 2021a), so there is a risk of conflating degradation impacts with sensitivity; we aimed to overcome this by asking for both good and degraded habitats to be assessed.

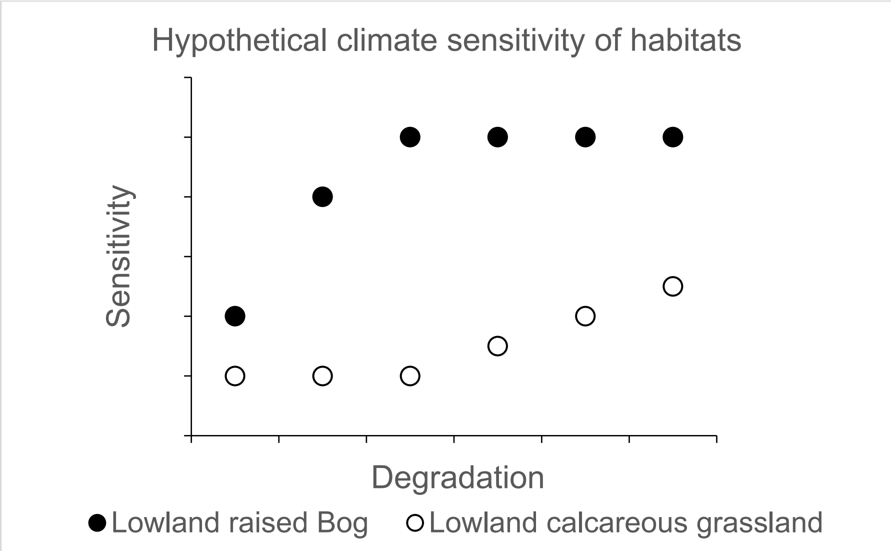

Figure 1. Hypothetical impact of habitat degradation on the sensitivity of the habitat to climate change. Example of lowland raised bog and lowland calcareous grassland.

1.4 The approach.

The project was designed to engage with experts, both academic and practitioners in other sectors, to refine our understanding of both these elements. This assessment was qualitative in nature and based on expert judgement. An iterative Delphi-based approach (Ilbery *et al*. 2004) to score the sensitivity of habitats to climate change on a 5-point scale was used. The Delphi methods is specifically designed to avoid problems associated with group thinking, group bias and groups confirming to a majority view. It was also designed as a forecasting and decision-making tool (Gupta & Clarke, 1996). The main benefit of the Delphi Technique was its ability to obtain a consensus of opinion between the experts involved in the project. In order to tackle the issue of habitat status (i.e. good or degraded) a dual scoring of habitats was undertaken by the expert participants in the Delphi process: (1) ranking of sensitivity of good habitat to climate change; and (2) ranking of sensitivity of degraded habitat to climate change, where the level of degradation is the average degradation of that habitat in England. The types of degradation that were to be considered are included in the section immediately below.

1.5 Habitat Degradation

Most UK habitats are degraded to a certain extent (ONS 2022) and this is also so for priority habitats (UK Government 2021a; Nature Scotland 2019). The degradation pressures affect the resilience of habitats but in theory does not affect the inherent sensitivity of habitat to external perturbations. Degradation pressures may affect the habitat in numerous and different ways, which is largely dependent on what that pressure is. For example, pressures may alter the species composition within that habitat or reduce the habitats functionality for species. Key degradation pressures are summarised below. The degradation pressures listed cover broad UK habitat types, which can be linked to the more specific sub-category habitats in the list provided. Although the specifics of the degradation pressure for habitats in a particular locality were not to be considered, it is useful to clarify the sort of degradations which might have resulted in degraded habitats; in this Delphi expert consulting however, it was the average condition of a habitat across the UK that was to be focussed on.

1.5.1 Agricultural pressure.

Agricultural intensification is an important driver of biodiversity loss (Tscharntke *et al.* 2005). A number of species rely on agricultural habitats with less intensive management, which require careful management. Currently, 72% of the UK's land area is managed for agriculture, with one third arable and two-thirds pastoral (grassland, moor and heath). This is included within 'changes in land management' and 'changes in species distribution' pressures highlighted in Figure 2, with upland areas in particular degraded by these pressures. A key indicator of biodiversity loss in agriculture is the decline of farmland birds, with a decrease of 54% since 1970 (Defra 2021).

1.5.2 Hydrological management.

Many of the pressures affecting the distribution and quality of freshwater habitats relate to historical land drainage, much of which is linked to agricultural management. Upland drainage reduces carbon storage and contributes to lowland flooding. Land-cover maps show that between 2006 and 2012 over 1,000ha of wetland was converted to artificial surfaces (The Wildlife Trusts 2022). Up to 90% of lowland ponds in the UK have been lost, those remaining face increasing pressure due to agricultural land drainage, pollution, isolation and urban development (Environment Agency 2019a). Managed freshwater fisheries can have negative impacts on the ecology and functioning of habitats by, for example, increasing pollution from waste products and altering the species composition of the site.

1.5.3 Pollution.

The most widespread current pollution is caused by excess nutrients, specifically phosphate and nitrogen (Isbell *et al*. 2013). However, pollutants come from a range of sources, including but not limited to plastic waste; chemicals in water, soil and air; noise and light emitted from settlements and transport; and nutrient enrichment of habitats. Eutrophication, acidification and toxic pollution of habitats drive declines in the presence, abundance and health of species. There is strong evidence that nutrient enrichment via nitrogen deposition has impacted plant species in a wide range of habitats (Bin-Le *et al*. 2021).

1.5.3 Urbanisation.

Urbanisation pressure leads to the direct loss of habitats. It also acts to fragment landscapes by creating barriers between habitats, thus isolating some populations and in turn reducing their genetic fitness. Direct land take from development affects a number of habitats, with heathland being one that has been most impacted by urban expansion (Haskins 2000).

1.5.4 Non-native species.

Currently, 12% of established non-native species have a demonstrated negative ecological or human impact. Impacts are measured across all ecosystems, particularly on native woodlands, freshwater habitats and islands. There are currently around 2,000 non-native species known to be established in the UK; an average of 10–12 new species establish each year, further impacting affected habitats (Defra 2015).

1.5.5 Changes in woodland management.

Ancient woodlands across the UK have been lost through conversion to plantation forestry and face continued threat from infrastructure and housing development. UK woodland cover increased by 9% between 1998 and 2018 and is currently estimated at 3.17 million ha (Forest Research 2018), much of this increase being conifer plantations. Scotland has seen the largest area increase (156,000ha), while Northern Ireland had the greatest proportional increase (39%) but remains the least wooded UK country. Increasing deer numbers (both native and non-natives) have a heightened impact on woodland (Staddon *et al*. 2021) and its dependent wildlife as they reduce natural regeneration and alter woodland structure through grazing and browsing.

1.5.6 Physical modification.

Direct alterations to a habitat, such as for biological resource use or for energy production is another important pressure. Physical modifications including engineering works prevent natural habitat processes. An example of this is dams on water courses or building transport links (roads, rail etc) which fragment habitats. Physical modification is particularly apparent in rivers and streams (Figure 2). This is for fishery use, energy production and for resource extraction (Environment Agency 2019b).

Methodology

3.1 Habitat types – rationale for selection.

The habitats that were considered as part of the project were taken from the Priority Habitat Inventory (PHI) (UK Government 2021b), but for different reasons there were several exceptions.

First, river categories were split down to a finer scale than the PHI classification and upland acid grassland was added:

- River typology used EUNIS descriptors (EEA 2022) as it was considered that the PHI rivers classification is too broad to enable a representative assessment of sensitivity.
- Upland acid grassland was added. This is a non-PHI class but has a JNCC description.

Second, heathland, lowland meadow and coastal and floodplain grazing marsh PHI classes were split into sub-categories that better reflect the likely differential impact and thus sensitivity to climate change:

- Upland and lowland heath (PHI) were separated into wet and dry sub-categories. EUNIS descriptions of these were provided.
- Lowland meadow (PHI) was separated into wet and dry sub-categories.
- Coastal and floodplain grazing marsh (PHI) was split into floodplain and coastal sub-categories.

In these cases, the distinction between sub-categories was based on a coarse view of the main influencing factor i.e. wet *vs* dry or riverine *vs* coast. It is acknowledged that this was a relatively arbitrary distinction and in each case gradients of influence exist. Nonetheless we felt that this was necessary as key climate change drivers would likely be quite different between the sub-categories identified.

The full list of habitats is provided in Table 1.

Table 1. List of habitats to be assessed for sensitivity to climate change.

Broad habitat	Priority, EUNIS or derived habitat
Rivers and streams	Base-poor spring and spring brook
	Calcareous spring and spring brook
	Permanent non-tidal, fast, turbulent watercourse of montane to alpine regions with mosses
	Permanent non-tidal, fast, turbulent watercourse of plains and montane regions with Ranunculus spp
	Permanent non-tidal, smooth-flowing watercourse
	Tidal river, upstream from the estuary
	Temperate temporary running watercourse
Standing open waters and canals	Oligotrophic and Dystrophic Lakes
	Ponds
	Mesotrophic Lakes
	Eutrophic Standing Waters
	Aquifer Fed Naturally Fluctuating Water Bodies
Arable and horticultural	Arable Field Margins
Boundary and Linear Features	Hedgerows
Broadleaved, Mixed and Yew Woodland	Traditional Orchards
	Wood-Pasture and Parkland
	Upland Oakwood
	Lowland Beech and Yew Woodland
	Upland Mixed Ashwoods
	Wet Woodland
	Lowland Mixed Deciduous Woodland
	Upland Birchwoods
Coniferous Woodland	Native Pine Woodlands
Acid Grassland	Lowland Dry Acid Grassland
	Upland Acid Grassland
Calcareous Grassland	Lowland Calcareous Grassland
	Upland Calcareous Grassland
Neutral Grassland	Dry Lowland Meadows
	Wet Lowland Meadows
	Upland Hay Meadows
Improved Grassland	Coastal Grazing Marsh
	Floodplain Grazing Marsh
Dwarf Shrub Heath	Wet Lowland Heath
	Dry Lowland Heath
	Wet Upland Heath
	Dry Upland Heath
Fen, Marsh and Swamp	Upland Flushes, Fens and Swamps
	Purple Moor Grass and Rush Pastures
	Lowland Fens

Broad habitat	Priority, EUNIS or derived habitat
	Reedbeds
Bogs	Raised Bog (PHI Lowland Raised Bog)
	Blanket Bog
Montane Habitats	Mountain Heaths and Willow Scrub
Inland Rock	Inland Rock Outcrop and Scree Habitats
	Calaminarian Grasslands
	Limestone Pavements
	Maritime Cliff and Slopes
Supralittoral Sediment	Coastal Vegetated Shingle
	Machair
	Coastal Sand Dunes
Littoral Sediment	Coastal Saltmarsh
	Intertidal Mudflats
Sublittoral Sediment	Saline Lagoons

3.2 The Delphi method.

As explained above, the Delphi approach was designed for eliciting responses by experts or stakeholders whilst avoiding issues linked to group thinking, group bias and group pressure to conform to a majority view (Mukherjee *et al*. 2015). A key attribute of the Delphi method is that it allows the researcher to facilitate the emergence of a consensus of opinion between the experts or stakeholders involved in the process (Ilbery *et al.* 2004). The Delphi method has three key characteristics which aid in an impartial and objective consensus formation:

- There is anonymity between participants;
- The participants are chosen as experts in the subject matter;
  It is a partly iterative process with at least two rounds of communication between the researcher and the participants (Chiswell *et al.* 2021)

3.2.1 Delphi preparations.

An iterative Delphi approach was developed for this project. In total, 22 experts were invited to participate. This is a above the minimum of 15 required for the process to be considered robust. This was deliberate to ensure the numbers engaged at the end of the process were sufficient. The project Steering group's assistance in identifying these experts was crucial in achieving a good mix of specialities (e.g. habitat types) between and climate change impacts specialists, who would have a more cross-habitat viewpoint. Experts were also chosen to represent a range of views from academia, government agencies, non-governmental bodies, to cover the whole of Britain (i.e. located in England, Scotland and Wales), and to not be overly dominated by middle aged white males. The following organisations were represented: Natural England, Natural Resources Wales, Nature Scotland, Wildlife Trusts, Forestry Commission, RSPB, and four universities. The initial invitation to take part in the study is provided in Appendix 1.

3.2.2 Consent and information.

Informed consent was obtained from the experts participating in the study before the process started. Experts were given assurances of confidentiality and anonymity, and although their names and contact details were collected as part of the survey, this was for internal use only, in order to distinguish those who had completed it from those who had not. Supporting information was prepared and forwarded to participants so the tasks expected were carried out as consistently and efficiently as possible by all expert participants (appendix 2). The engagement process was coordinated by CCRI staff, including the sending of reminders where necessary. Therefore, the responses were only known by the project team, to preclude any potential prejudice in analysing the respondents scoring and comments.

3.3 First round.

In the first round, the participants were provided with the task of assigning British habitats to a 5-point scale of sensitivity to climate change. This was carried out twice for each of the habitats depending on two assumptions about their status: that habitats are in (1) good condition; and (2) their *average* degraded condition for the UK (i.e. degraded to some extent) (See sections 1.3 and 2 for definitions and further explanation). Background information on projected climate change was provided to participants. This would minimise risks that they might be starting from vastly different points as to what climate change will mean for Britain in terms of temperature, precipitation and changes in intensity and frequency of extreme weather events.

The key elements of this information were that global warming of 1.5°C - 2°C is predicted to occur during the 21st century (IPCC 2022) even if CO_2 and other greenhouse gas emissions are reduced significantly. An increase in flooding attributed to human influence will further increase with global warming. There will also be an increase in storm and other extreme weather, with the UK as no exception. Within the UK, summer temperatures will increase more than winter, leading to increased heatwaves and spreading of hot summers from the south east to further north. In conjunction with warming, projections suggest a reduction in precipitation in summers but an increase in the winter with potentially increased intensity (Met Office, 2022). Warmer, drier weather will lead to increased drought and with that increased fire risk. 2°C global warming is projected to double the number of fire days in comparison to the recent historical period, with a 150% increase for England at 2°C of global warming, highlighting the emerging and more widespread fire risk in the UK with climate change (Perry *et al*. 2021).

Each participant was asked to independently place each habitat on the 5-point sensitivity scale for both ‘good habitats’ and ‘degraded habitats’. Participants were also asked to briefly justify their scoring for each habitat and provide any key pieces of evidence they were relying on, with particular reference to any grey literature. Participants were also asked to self-describe their level of expertise for each habitat as either high, medium or low. The purpose being to assess whether there might be any differences in responses based on the respondent's expertise (Full details in Appendix 3). In total 21 out of 22 responses were received, with 15 respondents completing the whole task; 2 respondents only completed the good status habitats, but commented they did not see a difference in sensitivity between good and degraded habitats; 4 respondents only scored the few habitats they considered themselves experts in.

3.3.1 Consolidation of first round responses.

The results were analysed and amalgamated into suggested consensus views for both the 'good habitat' and 'degraded habitat' assessment. Two sets of analysis were undertaken. The first compared the means of values for the scores for each habitat type as submitted. The second analysis weighted the scores based on expertise (Hasson *et al*. 2008), with low expertise weighted 1, medium expertise weighted 3 and high expertise weighted 5; this weighting was chosen over a weighting of 1, 2 and 3 to add more significance to high expertise which should lead to robust scoring. The weighted means were then obtained. A third analysis was then performed to recalibrate all the scores across both the good and degraded habitats to a range of 1 to 5; this was necessary as there was a tendency for the scores to pull to the mean, which is expected for this type of analysis.

The impact of this is discussed in Section 4, and the decision taken to proceed to Round 2 with the weighted scores. The recalibrated version of the weighted mean scores was chosen as the most useful consolidated version to circulate in round 2.

3.4 Delphi second round.

In the second Round of Delphi, the two consensus views obtained after the round 1 analysis were circulated to all the participants for commentary and suggestions of where there might be issues requiring further clarification. This enabled the participants, including the one who did not submit a response, to compare their original scoring with the consensus view. This provided an opportunity for respondents to raise issues either where they originally scored significantly different from the consensus view or where they see something odd in the relative scoring between habitats. It would also allow those who view themselves as experts in a particular habitat to raise a point regarding the consensus score rather than those who did not consider themselves to be experts in that particular habitat. It was made clear to the participants of the need to identify anything that looked at odds with their understanding of the habitats, their pressures and their likely sensitivity to climate change; specific issues identified by the researchers were not highlighted so as not to influence the expert consensus outcome. (See Appendix 4). A total of 18 out of 22 responses was received. Of these, 13 respondents provided commentary on which scores might deserve being adjusted and a suggested amended score for a selection of habitats where they felt there was an issue; 4 respondents either confirmed they were happy with the scores or provided a brief, but not particular useful comment; 1 respondent provided detailed comments on selected habitats but no actual suggested score.

3.4.1 Consolidation of second round responses.

The justification of the respondents for any changes to the consolidated Round 1 scores were considered for each habitat in both ‘good’ or ‘degraded’ status. Suggested changes were accepted where one or more of the following conditions were met:

(1) several respondents were independently saying the same thing;
(2) the justification was scientifically robust and referred to available evidence;
(3) inconsistencies in scoring were identified either between closely related habitats or between good and degraded habitats.

Where there were diametrically opposing requests for score adjustments based on valid but differing justifications, no change was made and the original consensus score was kept.

3.5 Delphi third and final round.

The round three outputs were based on the consensus-based outputs from Round 2, which was robust in that it was accepted by the vast majority of participants with only a few relatively minor disagreements (mostly differences in adjoining scores). No participant fundamentally disagreed with the consensus view. The third and final round allowed the respondents to see the final consensus view and make any final comments on the sensitivity scoring that the habitats received. At this point, no new comments were received.

Results

The results are presented by round and first split between good and degraded status habitats; comparison of responses for habitats of different status are also provided.

4.1 Round 1 results for good status habitats.

Most respondents filled in the whole table as requested, although 4 respondents only filled in those few habitats they were specialist in. The unweighted consolidated scores for each habitat are presented in Table 2. Of note is that the consolidated (averaged) scores resulted in no habitats being scored 4 or 5. However the standard deviation was high with most habitats having a range of scores covering 4 or even 5 of the possible brackets.

To take the expertise of respondents with regard to different habitats into account, the scores were then weighted by expertise and are presented in Table 3. There are some differences to the unweighted picture, but the general outcome is strikingly similar. The weighted consolidated scores are slightly stretched and there is one case of a score of 4 being picked up.

Clearly, because of the averaging process the consolidated scores are pulled to the medium value, leading to the need for a rescaling to occur. The rescaling was based on the full range of weighted scores for both the good and the degraded habitats so that comparisons between the two would remain valid. The rescaled scores are presented in Table 4. For the good habitats the scores are spread across the 1 to 4 brackets but none reach the highest bracket (however scores in this bracket are observed for degraded habitats – see next section).

A summary of key words used in the justification is provided in Table 5. These highlight the most common justification provided by respondents for the scores provided for each habitat. Note that not all commentary is provided here.

Table 2. Consolidated results from round 1 for good habitats. The average score provided by each respondent was obtained. The actual calculated value is provided in the 'average sensitivity' column along with the standard deviation. These averages are then represented with an 'X' in the scoring table.

Habitat	Sensitivity to Climate Change Unweighted average					Average sensitivity	Standard deviation
	Low		Mid		High		
	1	2	3	4	5		
Base-poor spring and spring brook			X			**3.8**	0.98
Calcareous spring and spring brook			X			**3.7**	1.16
Permanent non-tidal, fast, turbulent watercourse of montane to alpine regions with mosses			X			**3.4**	0.94
Permanent non-tidal, fast, turbulent watercourse of plains and montane regions with Ranunculus spp			X			**3.2**	0.83
Permanent non-tidal, smooth-flowing watercourse			X			**3.0**	0.87
Tidal river, upstream from the estuary			X			**3.1**	1.20
Temperate temporary running watercourse			X			**3.6**	1.18
Oligotrophic and Dystrophic Lakes			X			**3.4**	0.93
Ponds			X			**3.6**	1.11
Mesotrophic Lakes			X			**3.1**	0.93
Eutrophic Standing Waters			X			**3.0**	0.79
Aquifer Fed Naturally Fluctuating Water Bodies			X			**3.2**	1.33
Arable Field Margins	X					**1.8**	1.15
Hedgerows	X					**1.8**	0.81
Traditional Orchards		X				**2.2**	0.97
Wood-Pasture and Parkland		X				**2.5**	1.18
Upland Oakwood		X				**2.9**	1.25
Lowland Beech and Yew Woodland			X			**3.2**	1.15
Upland Mixed Ashwoods		X				**2.9**	1.17

Habitat	Sensitivity to Climate Change Unweighted average					Average sensitivity	Standard deviation
	Low		Mid		High		
	1	2	3	4	5		
Wet Woodland			X			**3.4**	0.93
Lowland Mixed Deciduous Woodland		X				**2.2**	1.03
Upland Birchwoods		X				**2.9**	1.22
Native Pine Woodlands		X				**2.8**	1.42
Lowland Dry Acid Grassland		X				**2.4**	1.20
Upland Acid Grassland		X				**2.3**	0.96
Lowland Calcareous Grassland		X				**2.2**	1.01
Upland Calcareous Grassland		X				**2.1**	0.86
Dry Lowland Meadows		X				**2.4**	0.93
Wet Lowland Meadows			X			**3.1**	1.17
Upland Hay Meadows			X			**3.1**	1.03
Coastal Grazing Marsh			X			**3.4**	1.09
Floodplain Grazing Marsh			X			**3.0**	0.73
Wet Lowland Heath			X			**3.6**	0.62
Dry Lowland Heath			X			**3.1**	0.94
Wet Upland Heath			X			**3.0**	0.49
Dry Upland Heath		X				**2.8**	0.73
Upland Flushes, Fens and Swamps			X			**3.3**	0.85
Purple Moor Grass and Rush Pastures		X				**2.8**	0.65
Lowland Fens			X			**3.5**	0.87
Reedbeds		X				**2.6**	0.87
Raised Bog (PHI Lowland Raised Bog)			X			**3.5**	0.83
Blanket Bog			X			**3.5**	0.72
Mountain Heaths and Willow Scrub			X			**3.8**	1.06
Inland Rock Outcrop and Scree Habitats		X				**2.2**	1.29
Calaminarian Grasslands		X				**2.1**	0.85

Habitat	Sensitivity to Climate Change Unweighted average					Average sensitivity	Standard deviation
	Low		Mid		High		
	1	2	3	4	5		
Limestone Pavements		X				**2.3**	1.05
Maritime Cliff and Slopes		X				**2.6**	1.23
Coastal Vegetated Shingle			X			**3.1**	1.15
Machair			X			**3.4**	1.04
Coastal Sand Dunes			X			**3.3**	0.76
Coastal Saltmarsh			X			**3.5**	1.31
Intertidal Mudflats			X			**3.2**	1.15
Saline Lagoons			X			**3.6**	1.42

Table 3. Consolidated weighted results from round 1 for good habitats. The weighted average score provided by each respondent was obtained. The scores for weighted 1, 3 and 5 for low, medium and high levels of expertise respectively. The actual calculated sensitivity value is provided in the 'weighted average' column. These averages are then represented with an 'X' in the scoring table.

Habitat	Sensitivity to climate change Expert weighted results					Weighted average
	Low		Mid		High	
	1	2	3	4	5	
Base-poor spring and spring brook				X		**4.0**
Calcareous spring and spring brook			X			**3.9**
Permanent non-tidal, fast, turbulent watercourse of montane to alpine regions with mosses			X			**3.5**
Permanent non-tidal, fast, turbulent watercourse of plains and montane regions with Ranunculus spp			X			**3.4**
Permanent non-tidal, smooth-flowing watercourse			X			**3.3**
Tidal river, upstream from the estuary			X			**3.3**
Temperate temporary running watercourse			X			**3.7**
Oligotrophic and Dystrophic Lakes			X			**3.6**
Ponds			X			**3.7**
Mesotrophic Lakes			X			**3.2**
Eutrophic Standing Waters			X			**3.2**
Aquifer Fed Naturally Fluctuating Water Bodies			X			**3.3**
Arable Field Margins	X					**1.7**
Hedgerows		X				**2.0**
Traditional Orchards		X				**2.1**
Wood-Pasture and Parkland (updated December 2011)		X				**2.7**
Upland Oakwood			X			**3.1**
Lowland Beech and Yew Woodland			X			**3.3**
Upland Mixed Ashwoods			X			**3.0**

Habitat	Sensitivity to climate change Expert weighted results					Weighted average
	Low		Mid		High	
	1	2	3	4	5	
Wet Woodland			X			3.2
Lowland Mixed Deciduous Woodland		X				2.2
Upland Birchwoods			X			3.0
Native Pine Woodlands			X			3.1
Lowland Dry Acid Grassland		X				2.6
Upland Acid Grassland		X				2.4
Lowland Calcareous Grassland		X				2.3
Upland Calcareous Grassland		X				2.4
Dry Lowland Meadows		X				2.5
Wet Lowland Meadows			X			3.3
Upland Hay Meadows			X			3.2
Coastal Grazing Marsh			X			3.4
Floodplain Grazing Marsh		X				2.9
Wet Lowland Heath			X			3.6
Dry Lowland Heath			X			3.2
Wet Upland Heath			X			3.0
Dry Upland Heath		X				2.7
Upland Flushes, Fens and Swamps			X			3.5
Purple Moor Grass and Rush Pastures		X				2.9
Lowland Fens			X			3.5
Reedbeds		X				2.4
Raised Bog (PHI Lowland Raised Bog)			X			3.3
Blanket Bog			X			3.4
Mountain Heaths and Willow Scrub			X			3.8
Inland Rock Outcrop and Scree Habitats	X					1.9
Calaminarian Grasslands		X				2.0
Limestone Pavements		X				2.5

Habitat	Sensitivity to climate change Expert weighted results					Weighted average
	Low		Mid		High	
	1	2	3	4	5	
Maritime Cliff and Slopes		X				**2.5**
Coastal Vegetated Shingle			X			**3.2**
Machair			X			**3.4**
Coastal Sand Dunes			X			**3.3**
Coastal Saltmarsh			X			**3.8**
Intertidal Mudflats			X			**3.6**
Saline Lagoons			X			**3.8**

Table 4. Rescaled consolidated weighted results from round 1 for good habitats. The rescaled weighted average score was recalculated based on the full range of weighted scores obtained in the both the good and degraded habitats. These rescaled weighted averages are then represented with an 'X' in the scoring table.

Habitat	Sensitivity to climate change Expert weighted results - rescaled				
	LOW		MID		HIGH
	1	2	3	4	5
Base-poor spring and spring brook				X	
Calcareous spring and spring brook				X	
Permanent non-tidal, fast, turbulent watercourse of montane to alpine regions with mosses				X	
Permanent non-tidal, fast, turbulent watercourse of plains and montane regions with Ranunculus spp			X		
Permanent non-tidal, smooth-flowing watercourse			X		
Tidal river, upstream from the estuary			X		
Temperate temporary running watercourse				X	
Oligotrophic and Dystrophic Lakes				X	
Ponds				X	
Mesotrophic Lakes			X		
Eutrophic Standing Waters			X		
Aquifer Fed Naturally Fluctuating Water Bodies			X		
Arable Field Margins	X				
Hedgerows	X				
Traditional Orchards	X				
Wood-Pasture and Parkland		X			
Upland Oakwood			X		
Lowland Beech and Yew Woodland			X		
Upland Mixed Ashwoods			X		
Wet Woodland			X		
Lowland Mixed Deciduous Woodland	X				
Upland Birchwoods			X		
Native Pine Woodlands			X		

Habitat	Sensitivity to climate change Expert weighted results - rescaled				
	LOW		MID		HIGH
	1	2	3	4	5
Lowland Dry Acid Grassland		X			
Upland Acid Grassland		X			
Lowland Calcareous Grassland		X			
Upland Calcareous Grassland		X			
Dry Lowland Meadows		X			
Wet Lowland Meadows			X		
Upland Hay Meadows			X		
Coastal Grazing Marsh			X		
Floodplain Grazing Marsh			X		
Wet Lowland Heath				X	
Dry Lowland Heath			X		
Wet Upland Heath			X		
Dry Upland Heath		X			
Upland Flushes, Fens and Swamps				X	
Purple Moor Grass and Rush Pastures			X		
Lowland Fens				X	
Reedbeds		X			
Raised Bog (PHI Lowland Raised Bog)			X		
Blanket Bog			X		
Mountain Heaths and Willow Scrub				X	
Inland Rock Outcrop and Scree Habitats	X				
Calaminarian Grasslands	X				
Limestone Pavements		X			
Maritime Cliff and Slopes		X			
Coastal Vegetated Shingle			X		
Machair			X		
Coastal Sand Dunes			X		

Habitat	Sensitivity to climate change Expert weighted results - rescaled				
	LOW		MID		HIGH
	1	2	3	4	5
Coastal Saltmarsh				X	
Intertidal Mudflats				X	
Saline Lagoons				X	

Table 5. Justification summary key words retrieved from the respondents' comments and justifications for the scored value for good status habitats.

Habitat	Summary of justification
Base-poor spring and spring brook	change in flows, drought
Calcareous spring and spring brook	change in flows, drought
Permanent non-tidal, fast, turbulent watercourse of montane to alpine regions with mosses	change in flows, rising temperature
Permanent non-tidal, fast, turbulent watercourse of plains and montane regions with Ranunculus spp	change in flows, temperature
Permanent non-tidal, smooth-flowing watercourse	change in flows, temperature and eutrophication
Tidal river, upstream from the estuary	change in flows, temperature, saline intrusion
Temperate temporary running watercourse	drought and eutrophication
Oligotrophic and Dystrophic Lakes	drought and eutrophication
Ponds	drought and eutrophication
Mesotrophic Lakes	drought and eutrophication
Eutrophic Standing Waters	drought and eutrophication
Aquifer Fed Naturally Fluctuating Water Bodies	drought / drying out
Arable Field Margins	high resilience, ruderal sps
Hedgerows	high resilience, deep-rooted sps
Traditional Orchards	resilient managed habitats, main risk is pests & diseases
Wood-Pasture and Parkland	resilient but risks from storms and pests & diseases
Upland Oakwood	drought, pests & diseases, wildfires

Habitat	Summary of justification
Lowland Beech and Yew Woodland	drought, pests & diseases, wildfires
Upland Mixed Ashwoods	storms, drought, pests & diseases
Wet Woodland	drought, pests & diseases, wildfires
Lowland Mixed Deciduous Woodland	good resilience, but risks from drought, pests & diseases, wildfires
Upland Birchwoods	drought, warming, pests and diseases
Native Pine Woodlands	drought, pests & diseases, wildfires, storms
Lowland Dry Acid Grassland	good resilience, main risk is drought
Upland Acid Grassland	good resilience, main risk is drought
Lowland Calcareous Grassland	good resilience, main risk is drought
Upland Calcareous Grassland	good resilience, main risk is drought
Dry Lowland Meadows	good resilience, main risk is drought
Wet Lowland Meadows	sensitive to drought / drying out
Upland Hay Meadows	drought and warmer temperature, risk of invasives
Coastal Grazing Marsh	sea level rise and coastal erosion
Floodplain Grazing Marsh	drying out and sea level rise
Wet Lowland Heath	drought and wildfire, risk of invasives
Dry Lowland Heath	wildfire and drought
Wet Upland Heath	wildfire and drought
Dry Upland Heath	relatively resilient, risks from wildfire, but also drought
Upland Flushes, Fens and Swamps	drought and drying out
Purple Moor Grass and Rush Pastures	drought risk
Lowland Fens	drought risk, but also flooding risk
Reedbeds	good resilience, drought main risk
Raised Bog (PHI Lowland Raised Bog)	drying out would allow invasives
Blanket Bog	drying out would allow invasives
Mountain Heaths and Willow Scrub	rising temperature main risk
Inland Rock Outcrop and Scree Habitats	high resilience
Calaminarian Grasslands	specialised sps, good resilience
Limestone Pavements	relatively resilient, depends on management
Maritime Cliff and Slopes	relatively resilient but erosion risk
Coastal Vegetated Shingle	sea level rise, erosion risk

Habitat	Summary of justification
Machair	sea level rise
Coastal Sand Dunes	sea level rise and drier sand dunes
Coastal Saltmarsh	sea level rise, coastal squeeze
Intertidal Mudflats	sea level rise, coastal squeeze, storms
Saline Lagoons	sea level rise, storms, rising temperatures

4.2 Round 1 results for degraded status habitats.

Most respondents filled in the whole table as requested, although 4 respondents only filled in those few habitats they were specialist in. Two respondents only filled in the good habitat sheets as they deemed that habitat sensitivity is not dependent on habitat status. The unweighted consolidated scores for each habitat are presented in Table 6. Of note is that the consolidated scores resulted in no habitats being scored 5. However, the standard deviation was high with most habitats having a range of scores covering 4 or even 5 of the possible brackets.

To take the expertise of respondents with regard to different habitats into account, the scores were then weighted by expertise and are presented in Table 7. There are some differences to the unweighted picture, but the general outcome is strikingly similar. The weighted consolidated scores are slightly stretched with a few additional scores of 4 being picked up.

Clearly, because of the averaging process the consolidated scores are pulled to the medium value, leading to the need for a rescaling to occur. The rescaling was based on the full range of weighted scores for both the good and the degraded habitats so that comparisons between the two would remain valid. The rescaled scores are presented in Table 8. For the degraded habitats the scores are spread across the 1 to 5 brackets but with only 1 in the lowest bracket (however scores in this bracket are more commonly observed for good habitats – see previous section).

A summary of key words used in the justification is provided in Table 9. These highlight the most common justification provided by respondents for the scores provided for each habitat. The degradation pressures in particular become noticeable as covariates with climate change variables themselves. Note that not all commentary is provided here.

Most degraded habitats, with a few rare exceptions, are scored higher for sensitivity to climate change than good status habitats (Figure 2).

Table 6. Consolidated results from round 1 for degraded habitats. The average score provided by each respondent was obtained. The actual calculated value is provided in the 'average sensitivity' column along with the standard deviation. These averages are then represented with an 'X' in the scoring table.

Habitat	Sensitivity to Climate Change Unweighted average					Average sensitivity	Standard deviation
	Low		Mid		High		
	1	2	3	4	5		
Base-poor spring and spring brook				X		**4.1**	0.95
Calcareous spring and spring brook				X		**4.1**	1.13
Permanent non-tidal, fast, turbulent watercourse of montane to alpine regions with mosses				X		**4.1**	0.88
Permanent non-tidal, fast, turbulent watercourse of plains and montane regions with Ranunculus spp				X		**4.0**	1.13
Permanent non-tidal, smooth-flowing watercourse			X			**3.8**	1.21
Tidal river, upstream from the estuary			X			**3.8**	1.32
Temperate temporary running watercourse				X		**4.1**	1.10
Oligotrophic and Dystrophic Lakes			X			**3.9**	0.88
Ponds				X		**4.2**	0.86
Mesotrophic Lakes			X			**3.9**	0.88
Eutrophic Standing Waters			X			**3.7**	0.96
Aquifer Fed Naturally Fluctuating Water Bodies			X			**3.5**	1.06
Arable Field Margins		X				**2.2**	1.15
Hedgerows		X				**2.3**	0.88
Traditional Orchards		X				**2.8**	1.26
Wood-Pasture and Parkland (updated December 2011)		X				**2.8**	1.21
Upland Oakwood			X			**3.4**	1.16
Lowland Beech and Yew Woodland			X			**3.7**	1.16
Upland Mixed Ashwoods			X			**3.1**	1.10

Habitat	Sensitivity to Climate Change Unweighted average					Average sensitivity	Standard deviation
	Low		Mid		High		
	1	2	3	4	5		
Wet Woodland			X			**3.7**	1.11
Lowland Mixed Deciduous Woodland		X				**2.7**	1.10
Upland Birchwoods			X			**3.3**	1.33
Native Pine Woodlands			X			**3.1**	1.33
Lowland Dry Acid Grassland		X				**2.9**	1.15
Upland Acid Grassland		X				**2.9**	0.92
Lowland Calcareous Grassland		X				**2.6**	1.01
Upland Calcareous Grassland		X				**2.7**	0.99
Dry Lowland Meadows		X				**2.8**	1.15
Wet Lowland Meadows			X			**3.5**	1.19
Upland Hay Meadows			X			**3.5**	1.30
Coastal Grazing Marsh			X			**3.4**	1.03
Floodplain Grazing Marsh			X			**3.3**	0.80
Wet Lowland Heath			X			**3.9**	0.89
Dry Lowland Heath			X			**3.6**	0.89
Wet Upland Heath			X			**3.7**	0.87
Dry Upland Heath			X			**3.3**	0.60
Upland Flushes, Fens and Swamps				X		**4.0**	1.00
Purple Moor Grass and Rush Pastures			X			**3.3**	1.08
Lowland Fens				X		**4.1**	0.99
Reedbeds			X			**3.3**	1.39
Raised Bog (PHI Lowland Raised Bog)				X		**4.3**	0.72
Blanket Bog				X		**4.5**	0.64
Mountain Heaths and Willow Scrub				X		**4.5**	0.89
Inland Rock Outcrop and Scree Habitats		X				**2.7**	1.29
Calaminarian Grasslands		X				**2.4**	0.91
Limestone Pavements		X				**2.8**	1.26

Habitat	Sensitivity to Climate Change Unweighted average					Average sensitivity	Standard deviation
	Low		Mid		High		
	1	2	3	4	5		
Maritime Cliff and Slopes			X			**3.1**	1.41
Coastal Vegetated Shingle			X			**3.9**	1.22
Machair			X			**3.9**	1.20
Coastal Sand Dunes				X		**4.1**	0.87
Coastal Saltmarsh				X		**4.1**	1.25
Intertidal Mudflats			X			**3.5**	1.03
Saline Lagoons			X			**3.9**	1.51

Table 7. Consolidated weighted results from round 1 for degraded habitats. The weighted average score provided by each respondent was obtained. The scores for weighted 1, 3 and 5 for low, medium and high levels of expertise respectively. The actual calculated sensitivity value is provided in the 'weighted average' column. These averages are then represented with an 'X' in the scoring table.

Habitat	Sensitivity to climate change Expert weighted results					Weighted average
	Low		Mid		High	
	1	2	3	4	5	
Base-poor spring and spring brook				X		4.6
Calcareous spring and spring brook				X		4.4
Permanent non-tidal, fast, turbulent watercourse of montane to alpine regions with mosses				X		4.3
Permanent non-tidal, fast, turbulent watercourse of plains and montane regions with Ranunculus spp				X		4.4
Permanent non-tidal, smooth-flowing watercourse				X		4.2
Tidal river, upstream from the estuary				X		4.1
Temperate temporary running watercourse				X		4.4
Oligotrophic and Dystrophic Lakes				X		4.3
Ponds				X		4.4
Mesotrophic Lakes				X		4.4
Eutrophic Standing Waters				X		4.3
Aquifer Fed Naturally Fluctuating Water Bodies			X			3.6
Arable Field Margins		X				2.1
Hedgerows		X				2.3
Traditional Orchards		X				2.6
Wood-Pasture and Parkland		X				2.7
Upland Oakwood			X			3.3
Lowland Beech and Yew Woodland			X			3.7
Upland Mixed Ashwoods			X			3.0
Wet Woodland			X			3.4

Habitat	Sensitivity to climate change Expert weighted results					Weighted average
	Low		Mid		High	
	1	2	3	4	5	
Lowland Mixed Deciduous Woodland		X				2.7
Upland Birchwoods			X			3.5
Native Pine Woodlands			X			3.0
Lowland Dry Acid Grassland			X			3.1
Upland Acid Grassland			X			3.1
Lowland Calcareous Grassland		X				2.8
Upland Calcareous Grassland			X			3.0
Dry Lowland Meadows		X				2.9
Wet Lowland Meadows			X			3.7
Upland Hay Meadows			X			3.6
Coastal Grazing Marsh			X			3.6
Floodplain Grazing Marsh			X			3.3
Wet Lowland Heath			X			3.8
Dry Lowland Heath			X			3.6
Wet Upland Heath			X			3.6
Dry Upland Heath			X			3.3
Upland Flushes, Fens and Swamps				X		4.1
Purple Moor Grass and Rush Pastures			X			3.5
Lowland Fens			X			3.9
Reedbeds		X				2.9
Raised Bog (PHI Lowland Raised Bog)				X		4.1
Blanket Bog				X		4.4
Mountain Heaths and Willow Scrub				X		4.4
Inland Rock Outcrop and Scree Habitats		X				2.5
Calaminarian Grasslands		X				2.4
Limestone Pavements			X			3.0
Maritime Cliff and Slopes			X			3.0

Habitat	Sensitivity to climate change Expert weighted results					Weighted average
	Low		Mid		High	
	1	2	3	4	5	
Coastal Vegetated Shingle				X		**4.0**
Machair			X			**3.5**
Coastal Sand Dunes				X		**4.5**
Coastal Saltmarsh				X		**4.2**
Intertidal Mudflats				X		**4.0**
Saline Lagoons			X			**3.7**

Table 8. Rescaled consolidated weighted results from round 1 for degraded habitats. The rescaled weighted average score was recalculated based on the full range of weighted scores obtained in the both the good and degraded habitats. These rescaled weighted averages are then represented with an 'X' in the scoring table.

Habitat	Sensitivity to climate change Expert weighted results - rescaled				
	LOW		MID		HIGH
	1	2	3	4	5
Base-poor spring and spring brook					X
Calcareous spring and spring brook					X
Permanent non-tidal, fast, turbulent watercourse of montane to alpine regions with mosses					X
Permanent non-tidal, fast, turbulent watercourse of plains and montane regions with Ranunculus spp					X
Permanent non-tidal, smooth-flowing watercourse					X
Tidal river, upstream from the estuary					X
Temperate temporary running watercourse					X
Oligotrophic and Dystrophic Lakes					X
Ponds					X
Mesotrophic Lakes					X
Eutrophic Standing Waters					X
Aquifer Fed Naturally Fluctuating Water Bodies				X	

Habitat	Sensitivity to climate change Expert weighted results - rescaled				
	LOW		**MID**		**HIGH**
	1	**2**	**3**	**4**	**5**
Arable Field Margins	X				
Hedgerows		X			
Traditional Orchards		X			
Wood-Pasture and Parkland (updated December 2011)		X			
Upland Oakwood			X		
Lowland Beech and Yew Woodland				X	
Upland Mixed Ashwoods			X		
Wet Woodland			X		
Lowland Mixed Deciduous Woodland		X			
Upland Birchwoods				X	
Native Pine Woodlands			X		
Lowland Dry Acid Grassland			X		
Upland Acid Grassland			X		
Lowland Calcareous Grassland		X			
Upland Calcareous Grassland			X		
Dry Lowland Meadows			X		
Wet Lowland Meadows				X	
Upland Hay Meadows				X	
Coastal Grazing Marsh				X	
Floodplain Grazing Marsh			X		
Wet Lowland Heath				X	
Dry Lowland Heath				X	
Wet Upland Heath				X	
Dry Upland Heath			X		
Upland Flushes, Fens and Swamps					X
Purple Moor Grass and Rush Pastures				X	
Lowland Fens				X	

Habitat	Sensitivity to climate change Expert weighted results - rescaled				
	LOW		MID		HIGH
	1	2	3	4	5
Reedbeds			X		
Raised Bog (PHI Lowland Raised Bog)					X
Blanket Bog					X
Mountain Heaths and Willow Scrub					X
Inland Rock Outcrop and Scree Habitats		X			
Calaminarian Grasslands		X			
Limestone Pavements			X		
Maritime Cliff and Slopes			X		
Coastal Vegetated Shingle				X	
Machair				X	
Coastal Sand Dunes					X
Coastal Saltmarsh					X
Intertidal Mudflats				X	
Saline Lagoons				X	

Table 9. Justification summary key words retrieved from the respondents' comments and justifications for the scored value for degraded status habitats

Habitat	Summary of justification
Base-poor spring and spring brook	degraded riparian zone; temperature stress and drought
Calcareous spring and spring brook	eutrophication, temperature and flow
Permanent non-tidal, fast, turbulent watercourse of montane to alpine regions with mosses	degraded riparian zone; temperature stress and drought
Permanent non-tidal, fast, turbulent watercourse of plains and montane regions with Ranunculus spp	water flows, drought and temperature
Permanent non-tidal, smooth-flowing watercourse	water flows, drought and temperature
Tidal river, upstream from the estuary	water flows, drought and temperature, salinity increase

Habitat	Summary of justification
Temperate temporary running watercourse	eutrophication and drought, temperature
Oligotrophic and Dystrophic Lakes	eutrophication and drought, temperature
Ponds	eutrophication and drought, temperature
Mesotrophic Lakes	eutrophication and drought, temperature
Eutrophic Standing Waters	eutrophication and drought, temperature
Aquifer Fed Naturally Fluctuating Water Bodies	water level, drought
Arable Field Margins	ruderal sps, resilient to disturbance
Hedgerows	deep rooted species, higher resilience
Traditional Orchards	storms, drought, heatwaves, pests and diseases
Wood-Pasture and Parkland	storms, drought, heatwaves, pests and diseases
Upland Oakwood	storms, wildfires, pests and diseases
Lowland Beech and Yew Woodland	storms, drought, wildfires, pests and diseases
Upland Mixed Ashwoods	storms, drought, pests and diseases
Wet Woodland	drought, temperature, pests & diseases
Lowland Mixed Deciduous Woodland	storms, drought, wildfires, pests and diseases
Upland Birchwoods	storms, drought, wildfires, pests and diseases
Native Pine Woodlands	storms, wildfires, pests and diseases
Lowland Dry Acid Grassland	drought
Upland Acid Grassland	drought
Lowland Calcareous Grassland	relative good resilience, drought, wildfire
Upland Calcareous Grassland	drought, wildfire
Dry Lowland Meadows	drought, temperature
Wet Lowland Meadows	drought, water level
Upland Hay Meadows	drought, temperature
Coastal Grazing Marsh	drought, sea level rise
Floodplain Grazing Marsh	drought, water level
Wet Lowland Heath	drought, fire, invasives
Dry Lowland Heath	drought, fire, invasives

Habitat	Summary of justification
Wet Upland Heath	drought, fire, invasives
Dry Upland Heath	drought, fire
Upland Flushes, Fens and Swamps	drought, invasives
Purple Moor Grass and Rush Pastures	drought
Lowland Fens	drought
Reedbeds	hydrological changes, saline intrusion
Raised Bog (PHI Lowland Raised Bog)	hydrological changes, invasives
Blanket Bog	hydrological changes, invasives
Mountain Heaths and Willow Scrub	warming, invasives
Inland Rock Outcrop and Scree Habitats	relatively resilient, some climate risk
Calaminarian Grasslands	relatively resilient, high metals keep out competitors
Limestone Pavements	invasives, drought
Maritime Cliff and Slopes	sea level rise, storms
Coastal Vegetated Shingle	sea level rise, storms
Machair	sea level rise, storms, coastal squeeze
Coastal Sand Dunes	sea level rise, storms, coastal squeeze
Coastal Saltmarsh	sea level rise, storms, coastal squeeze
Intertidal Mudflats	sea level rise, storms, coastal squeeze
Saline Lagoons	sea level rise, storms, warming, coastal squeeze

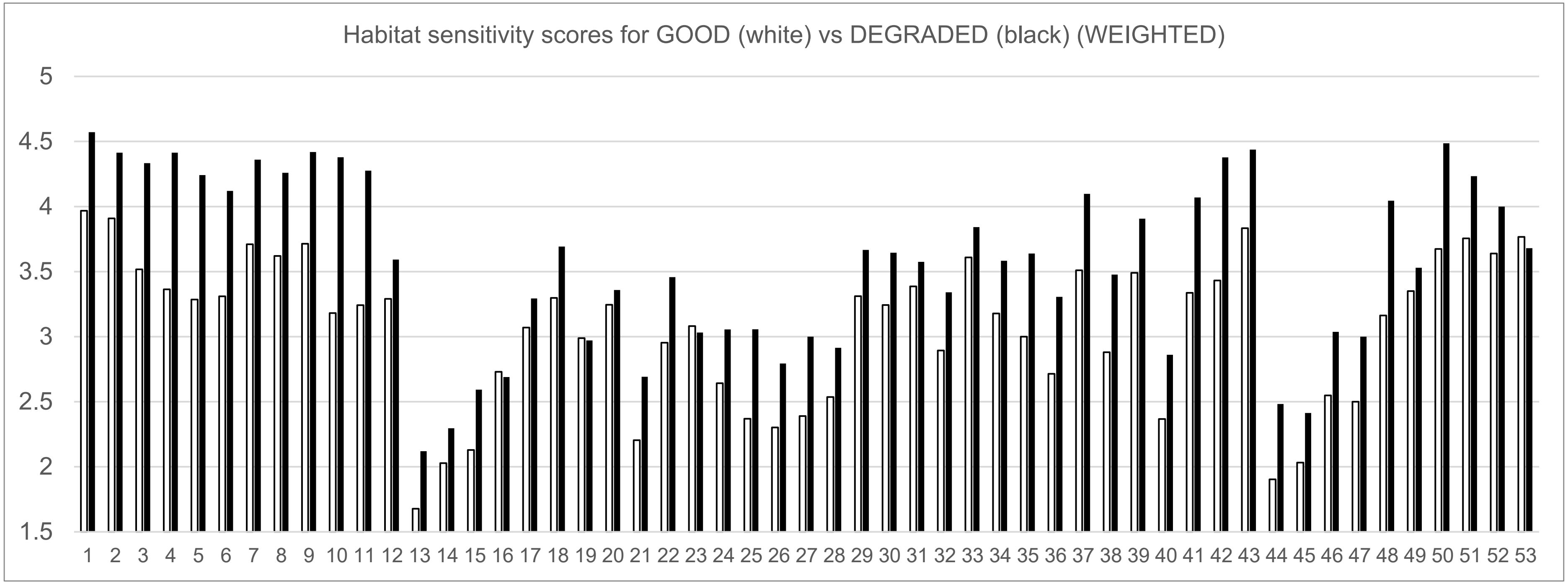

Figure 2. Overview of change in habitat sensitivity scores between good status habitats (white) and degraded status habitats (black). The numbers are linked to the habitats in the order of those in Table 1. The general picture is that degraded habitats all have a higher score than good status habitats, with a few rare exceptions where there are no big differences.

4.3 Round 2 results for good status habitats

Suggestions were made to tweak the score for many of the habitats, however a firm basis was required to do so as there was already strong consensus for the scores consolidated from round 1. Scores were only changed in the following cases: (1) several respondents independently arrived at the same suggestion with justification; (2) a crucial piece of (new) information was provided justifying the change; (3) inconsistencies were pointed out either between similar habitats or between habitats of good and degraded status. Clearly to maintain the consensus other requests for modifications could not be accepted. The changes are shown in Table 10.

The justifications were as follows:

a. Aquifer Fed Naturally Fluctuating Water Bodies: four respondents suggested this should be a 4 as they are relatively shallow and particularly at risk from drought.
b. Lowland Beech and Yew Woodland: three respondents suggested this should be a 4 as beech is particularly sensitive to summer drought.
c. Wet Woodland: respondents noted that these systems are particularly sensitive to drought; raised to 4.
d. Lowland Mixed Deciduous Woodland: compared to other related systems, this had a very low score, brought closer to other woodlands especially as others had their scores raised; increased to 2.
e. Native Pine Woodland: a specialist noted these are sensitive to wildfire, which is a significant increasing risk; raised to 4.
f. Wet Lowland Meadows: respondents note that this habitat is at risk from both flooding and drought; impacts would be through extended periods of anoxia as well as sedimentation; raised to 4.
g. Coastal Grazing Marsh: sea level rise could have severe consequences for this habitat; raised to 4.
h. Dry Lowland Heath: wildfire is highlighted as a key risk; raised to 4.
i. Purple Moor Grass and Rush Pastures: respondents noted the role of hydrology in this system and risks associated with climate change along with other pressures; raised to 4.
j. Mountain Heaths and Willow Scrub: loss of environmental envelop likely to be key for this habitat type; raised to 5.
k. Maritime Cliffs and slopes: erosion identified as a significant risk along the uncertainty of human response; raised to 3.
l. Machair: risk from sea level rise, but in addition the requirement for a specific soil type meaning the habitat cannot migrate; raised to 4.

Table 10. Adjusted scoring based on suggestions from round 2 for good habitats. All values are based on those obtained at the end of round 1 and reflect weighting and rescaling (seen in Figure 5). The 'Xm' indicates where scores were modified in response to a convincing case.

Habitat	Sensitivity to climate change Expert weighted results - rescaled				
	LOW		MID		HIGH
	1	2	3	4	5
Base-poor spring and spring brook				X	
Calcareous spring and spring brook				X	
Permanent non-tidal, fast, turbulent watercourse of montane to alpine regions with mosses				X	
Permanent non-tidal, fast, turbulent watercourse of plains and montane regions with Ranunculus spp			X		
Permanent non-tidal, smooth-flowing watercourse			X		
Tidal river, upstream from the estuary			X		
Temperate temporary running watercourse				X	
Oligotrophic and Dystrophic Lakes				X	
Ponds				X	
Mesotrophic Lakes			X		
Eutrophic Standing Waters			X		
Aquifer Fed Naturally Fluctuating Water Bodies				**Xm**	
Arable Field Margins	X				
Hedgerows	X				
Traditional Orchards	X				
Wood-Pasture and Parkland		X			
Upland Oakwood			X		
Lowland Beech and Yew Woodland				**Xm**	
Upland Mixed Ashwoods			X		
Wet Woodland				**Xm**	
Lowland Mixed Deciduous Woodland		**Xm**			
Upland Birchwoods			X		
Native Pine Woodlands				**Xm**	

Habitat	Sensitivity to climate change Expert weighted results - rescaled				
	LOW		**MID**		**HIGH**
	1	**2**	**3**	**4**	**5**
Lowland Dry Acid Grassland		X			
Upland Acid Grassland		X			
Lowland Calcareous Grassland		X			
Upland Calcareous Grassland		X			
Dry Lowland Meadows		X			
Wet Lowland Meadows				**Xm**	
Upland Hay Meadows			X		
Coastal Grazing Marsh				**Xm**	
Floodplain Grazing Marsh			X		
Wet Lowland Heath				X	
Dry Lowland Heath				**Xm**	
Wet Upland Heath			X		
Dry Upland Heath		X			
Upland Flushes, Fens and Swamps				X	
Purple Moor Grass and Rush Pastures				**Xm**	
Lowland Fens				X	
Reedbeds		X			
Raised Bog (PHI Lowland Raised Bog)			X		
Blanket Bog			X		
Mountain Heaths and Willow Scrub					**Xm**
Inland Rock Outcrop and Scree Habitats	X				
Calaminarian Grasslands	X				
Limestone Pavements		X			
Maritime Cliff and Slopes			**Xm**		
Coastal Vegetated Shingle			X		
Machair				**Xm**	
Coastal Sand Dunes			X		

Habitat	Sensitivity to climate change Expert weighted results - rescaled				
	LOW		MID		HIGH
	1	2	3	4	5
Coastal Saltmarsh				X	
Intertidal Mudflats				X	
Saline Lagoons				X	

4.4 Round 2 results for degraded status habitats

The same process applied to degraded habitats as were applied to good habitats. The changes are shown in Table 11.

The justifications were as follows:

a. Aquifer Fed Naturally Fluctuating Water Bodies: to be consistent with the change to the good habitat; raised to 5.

b. Wood Pasture and Parkland: due to the number of old trees and risks from pests and diseases climate change poses substantial risk; raised to 3.

c. Upland Oakwood: to be consistent with the change to the good habitat; raised to 4.

d. Upland Mixed Ashwood: to be consistent with the change to the good habitat; raised to 4.

e. Wet Woodland: three respondents suggest this score be raised due to drought risk; raised to 4.

f. Lowland Mixed Deciduous Woodland: to be consistent with the change to the good habitat; raised to 3.

g. Native Pine Woodland: to be consistent with the change to the good habitat; raised to 4.

h. Lowland Calcareous Grassland: to be consistent with related habitats under similar broad pressure types; raised to 3.

i. Lowland Fens: two respondents note that these habitats are particularly vulnerable to drought (because of shallow rooted species) and eutrophication pressures; raised to 5.

j. Inland Rock Outcrop and Scree Habitats: significant components of the plant communities are sensitive to climatic changes; raised to 3.

k. Coastal Vegetated Shingle: degraded habitats often losing sediment with limited possibility of migrating; raised to 5

l. Machair: specialised habitat requiring appropriate soil, limited opportunity to migrate in response to sea level rise; raised to 5.

m. Intertidal Mudflats: to be consistent with the change to the good habitat; raised to 5.

n. Saline Lagoons: to be consistent with the change to the good habitat; raised to 5.

Table 11. Adjusted scoring based on suggestions from round 2 for degraded habitats. All values are based on those obtained at the end of round 1 and reflect weighting and rescaling (seen in Table 8). The 'Xm' indicates where scores were modified in response to a convincing case.

Habitat	Sensitivity to climate change Expert weighted results - rescaled				
	LOW		MID		HIGH
	1	2	3	4	5
Base-poor spring and spring brook					X
Calcareous spring and spring brook					X
Permanent non-tidal, fast, turbulent watercourse of montane to alpine regions with mosses					X
Permanent non-tidal, fast, turbulent watercourse of plains and montane regions with Ranunculus spp					X
Permanent non-tidal, smooth-flowing watercourse					X
Tidal river, upstream from the estuary					X
Temperate temporary running watercourse					X
Oligotrophic and Dystrophic Lakes					X
Ponds					X
Mesotrophic Lakes					X
Eutrophic Standing Waters					X
Aquifer Fed Naturally Fluctuating Water Bodies					**Xm**
Arable Field Margins	X				
Hedgerows		X			
Traditional Orchards		X			
Wood-Pasture and Parkland			**Xm**		
Upland Oakwood				**Xm**	
Lowland Beech and Yew Woodland				X	
Upland Mixed Ashwoods				**Xm**	
Wet Woodland				**Xm**	
Lowland Mixed Deciduous Woodland			**Xm**		
Upland Birchwoods				X	
Native Pine Woodlands				**Xm**	

Habitat	Sensitivity to climate change Expert weighted results - rescaled				
	LOW		MID		HIGH
	1	2	3	4	5
Lowland Dry Acid Grassland			X		
Upland Acid Grassland			X		
Lowland Calcareous Grassland			**Xm**		
Upland Calcareous Grassland			X		
Dry Lowland Meadows			X		
Wet Lowland Meadows				X	
Upland Hay Meadows				X	
Coastal Grazing Marsh				X	
Floodplain Grazing Marsh			X		
Wet Lowland Heath				X	
Dry Lowland Heath				X	
Wet Upland Heath				X	
Dry Upland Heath			X		
Upland Flushes, Fens and Swamps					X
Purple Moor Grass and Rush Pastures				X	
Lowland Fens					**Xm**
Reedbeds			X		
Raised Bog (PHI Lowland Raised Bog)					X
Blanket Bog					X
Mountain Heaths and Willow Scrub					X
Inland Rock Outcrop and Scree Habitats			**Xm**		
Calaminarian Grasslands		X			
Limestone Pavements			X		
Maritime Cliff and Slopes			X		
Coastal Vegetated Shingle					**Xm**
Machair					**Xm**
Coastal Sand Dunes					X

Habitat	Sensitivity to climate change Expert weighted results - rescaled				
	LOW		MID		HIGH
	1	2	3	4	5
Coastal Saltmarsh					X
Intertidal Mudflats					**Xm**
Saline Lagoons					**Xm**

4.5 Round 2 comments on the process and outcomes

It is worth highlighting some of the comments that respondents have provided with regards to the Delphi process and outcomes.

This exercise highlighted for one expert that the “most honest answer from any of [the respondents] is probably somewhere between ‘it depends’ and ‘dunno’”. For another expert, they found that the process really did appear to lead to the “the wisdom of the crowd”: they note that they rarely disagreed with the consolidated scores but that “some of the comments justifying the scores included misconceptions”.

There were clearly some misunderstandings from some respondents with regard to the inherent sensitivity of some habitats and their component species to climate change variables. Perception that some habitats are relatively high resilience may be due to less familiarity with those particular ecosystems. After round 1, a woodland specialist notes for example that they understand the need to integrate a range of views but also that the consensus formed may not be accurate. A montane specialist notes similar cases for montane systems such as inland rock outcrop and scree habitat, where some of the comments and perceptions are not wholly accurate. Clearly for some habitats, specialist knowledge is crucial in reaching a more robust assessment of the sensitivity score. It was noted that there was a potential tendency for dry lowland habitats to be receiving lower scores than expected. Freshwater habitats also proved quite tricky to reach consensus, in part because some of the comments may not have been wholly accurate, but also because of apparent disagreement between specialists in terms of likely impacts; e.g. diametrically opposing views on impact of drying on pond species. It was also noted by some respondents that rarer habitats might be more tricky for non-specialist to assess; this was the main reason for round 2 which aimed to identify exactly these cases.

The issue of good versus degraded habitats was mentioned by several respondents as a potential source of confusion for varying reasons. For example, it was pointed out by one respondent that depending on what the degradation is it could either have positive or negative impacts on the sensitivity to climate change. Other respondents noted that they were unable to determine how habitat status might impact sensitivity to climate change. Another respondent noted that habitats and specifically community assemblages will alter in response to climate change and the shift in species distribution; making it difficult to provide a status to a potentially continually changing habitat.

For some habitats, there may be the case that particular species are more sensitive to climate change than others and thus decline, whilst not necessarily impacting the status of the habitat in question; an example of this would be oaks in lowland mixed broadleaves woods. For habitats that are localised in space (e.g. coastal, or montane) the major element to their sensitivity is their ability to migrate of lack thereof; in which case any difference between good and degraded might be questionable.

Several respondents commented on the role of restoration and specifically how easy it is to restore degraded habitats to a good condition; there was an argument that the ease or difficulty in being able to restore a habitat should in some way be included in the assessment of sensitivity to climate change. It was unclear to what extent this would have been done by most respondents.

Comments from several respondents suggest they did not fully understand how the rescaling worked, in the sense that this resulted in no (one after round 2) habitats of good status being scored as highly sensitive. The scale adjusted the full range of scores from both the good and degraded habitats into 5 brackets; because the degraded habitats were generally scored higher than the good habitats across the board, it not wholly surprising that good habitats rarely received high scores as presumably it was acknowledged by the scorers that the degraded version deserved a higher score.

4.6 Round 3 check on final consensus view

The final consensus view was circulated to all participants to allow a final opportunity to voice any critical concerns. Participants had nothing further to add apart from some reiterating that they were happy with the consensus view.

Discussion and Conclusion

5.1 Methodological approach

The chosen Delphi method aimed to capture a consensus view, which it achieved, in the sense that the consensus result was accepted by all respondent as representing an acceptable consensus. One point to note however is the large variation in opinions returned by individual experts with regards to the scoring, highlighting how Delphi can overcome this issue of diversity of opinions to reach a consensus view (Gupta & Clarke, 1996). Despite only experts in ecology and habitats being chosen, some were not familiar with all habitats and at times justifications provided exhibited a lack of understanding of the ecology or requirements of particular habitats, as reported in respondents' feedback (see results). Nonetheless, it is noteworthy that despite this a robust and valid consensus emerged across the range of habitats selected (Hasson *et al*. 2008). The importance of multiple rounds with justifications from the respondents sent-back to the experts facilitated the acceptance of the consensus outcome even when quite different from an individual's original assessment, as reasons for differences are explained.

The respondents were asked to provide two sets of scores for habitat sensitivity to climate change, one for degraded habitats and one for good status habitats. This was explained and accepted by most respondents, but a few questioned this distinction or provided scores for good status habitats only. It was argued by some that the sensitivity of a habitats to climate change (or any other perturbation) is inherent to the habitat and not dependent on the status of the habitat. From a theoretical view, this may have some valid basis, but from pragmatic view, this is arguably not the case: a habitat that may have lost species or where ecosystem processes (food chain, nutrient cycling, carbon budget, hydrology) are already impaired is likely to exhibit altered ecosystem functioning and possibly lower resistance and resilience to outside perturbation, making it more sensitive to outside influences. As the consensus view clearly highlighted that the expert respondents consider degraded habitats generally more sensitive to climate change than non-degraded habitats, this distinction was a useful addition to our investigation.

Following on from the above, there is the possibility that habitats are degraded to different extents across the UK, which would not have been explicitly captured in our assessment. This could potentially have affected some of the scores where the perceived level of degradation could have been affected by the work locality of the respondents. Nonetheless the overall picture that degraded habitats are more sensitive to climate change than those of good status remains. There is also the issue that some habitats are localised and not distributed throughout the UK; this does not impact the outcome of our research, but does mean that comparative sensitivity between habitats is not always comparing habitats spread over the same geographical area (e.g. some might be found in northern regions only, whereas others are found across the UK).

5.2 Results in context

There were evident differences in sensitivity to climate change for the habitats investigated. Those habitats with relatively low sensitivity to climate change included: arable field margins, hedgerows, traditional orchards, wood-pasture and parkland, lowland mixed deciduous woodland, grasslands, dry lowland meadows, dry upland health, reedbeds, inland rock outcrop and scree habitats, calaminarian grasslands, limestone pavements. It is noteworthy that these habitats included managed agricultural habitats, grasslands and those habitats characterised by being of a dry nature. Those habitats with relatively high sensitivity to climate change included: spring and spring brooks, permanent fast watercourses with mosses, temporary running watercourse, oligotrophic and dystrophic lakes, ponds, aquifer-fed fluctuating water bodies, lowland beech and yew woodland, wet woodland, native pine woodlands, wet lowland meadows, coastal grazing marsh, wet lowland heath, dry lowland heath, upland flushes, fens and swamps, purple moor grass and rush pastures, lowland fens, machair, coastal saltmarsh, intertidal mudflats, saline lagoons. It is noteworthy that most of these habitats tend to be those dependent on or defined by surface water availability, and habitats of a coastal nature.

Similar types of habitats or those with similar environmental requirements tend to group in their sensitivity to climate change. This is particularly obvious for grasslands, freshwater habitats, and coastal habitats. Other habitat types, e.g. woodlands or heathlands, exhibit a broader range of sensitivities depending on the exact habitat and its' requirements or pressures. For example, dry upland heath is evaluated as being not very sensitive to climate change, whereas dry lowland heath is highly sensitive to climate change.

Those habitats with higher anthropogenic control (i.e. especially those linked to the management of agricultural landscapes) appear the least sensitive to climate change. In particular, these habitats include the highly disturbed arable field margins, hedgerows and traditional orchards. It is worth noting here however that these habitats are defined or characterised by the level of management rather than by species composition. It is of course highly possible that the species mix found in arable field margins, hedgerows or orchards will alter in response to climate change. This might also imply that those more natural or native habitats may require additional management to cope with climate change (e.g. hydrology management).

There was a very clear pattern of increasing sensitivity to climate change in response to habitat degradation (i.e. good versus degraded status) for the vast majority of habitats. Most habitats saw their sensitivity to climate change increase by 1 or 2 points on the 5-point scale. Only a few habitats showed no difference in sensitivity to climate change between degraded or good habitats: arable field margins, lowland beech and yew woodland, wet woodland, wet lowland meadows, grazing marsh, lowland heaths, purple moor grass, mountain heaths, native pine woodland. For these habitats, this would imply that the level of degradation is not impacting their sensitivity to climate change; this maybe because the habitat is already highly disturbed as in the case of field margins or the climate variable itself (precipitation or temperature) directly impacts the dominant species in these habitats. For all other habitats, degradation would likely be decreasing the adaptive capacity and / or resilience of the habitats to climate change thus making them more sensitive to climate change. This may be through stress pressures on individuals or species within the habitat or loss or certain species impacting habitat functioning.

For those habitats that showed a general increase in sensitivity to climate change when in a degraded condition compared to good condition, most showed a 1 point increase in sensitivity on the 5-point scale, but several showed an increase in sensitivity of 2 or more points: permanent fast watercourse with *Ranunculus* spp, permanent smooth flowing watercourse, tidal river, mesotrophic lakes, eutrophic standing water, raised bog, blanket bog, scree habitats, coastal vegetated shingle, coastal sand dunes. These particular habitats are at significantly enhanced risk in their sensitivity to climate change when in a degraded condition. These degraded habitats tend to be compromised by altered hydrology or coastal squeeze.

5.3 Implication and application

Climate change impacts are increasing leading to the urgent need to assist habitats and ecosystems to adapt to climate change. The work presented here shows that habitats clearly differ in their sensitivity to climate change, and this, in this instance, on a 5-point scale. The results allow prioritisation to take place at an improved resolution than previously where a 3-point scale was used. Taking both the sensitivity to climate change of good and degraded habitats into account, those that are most sensitive to climate change and require most assistance are easily identified. Focussing conservation or management efforts for climate change adaptation to those habitats most sensitive to climate change would seem to be a good use of limited resources. However, a caveat here is that some habitats that are highly sensitive to climate change may lose their environment/climate envelope in the UK, meaning that any effort spent on these would be in vain. It should also be noted, that the closer the habitats being considered for prioritisation ranking (e.g. all grasslands, or freshwater) the more robust the prioritisation will be. Similarly, comparison of habitats within a specific geographical area will be more robust than prioritisation of habitats in very different climate zones. As conservation and biodiversity plans and delivery occur at the county or region level, the above caveats are of limited concern.

How habitats respond to climate change will vary. Some habitats may keep a similar set of species, other may lose or gain species, and in some cases as noted above the environment / climate envelop may simply be longer suitable for a particular habitat which will be replaced by a different habitat. How sensitive habitats respond to climate change and to want extent the current habitat can be maintained under the new climate conditions needs considering for an appropriate course of action to be taken. It might be that for some habitats in some settings, preference must be to facilitate transition to a more suitably adapted habitat type; it might be possible to help those habitats which will no longer fit the environment / climate envelop to migrate (or translocate) but this may not always be practical. Pragmatic choices will need to be made with the goal of maintaining overall ecosystem services in a particular area, even if these are provided by a different habitat type.

For those habitats where sensitivity to climate change is strongly linked to degradation (i.e. where the difference in sensitivity between habitats in good or degraded condition is large), it would be sensible to tackle current degradation pressures as part of any adaptation to climate change. A key one which is evident in many of the habitats is the need to restore hydrology where this has been compromised by human activity. For coastal habitats, coastal squeeze is an existential issue as these habitats will not be able to move inland as sea level rises, and in effect will have nowhere to go.

To conclude, these results on habitat sensitivity to climate change allow prioritisation of habitats most sensitive to climate change. However, comparisons between habitats are most robust for similar habitats and habitats in the same geographical area. This means that the habitat sensitivity scores are likely to be of greatest interest and use at the level at which conservation and adaptation to climate change will be carried out (i.e. regional and sub-regional levels). It is also worth noting that how habitats might respond to climate change will need to be considered as in some instances it may be impossible to save a climate sensitive habitat *in-situ*. Finally, the interplay with degradation pressures must be considered especially where these significantly increase the sensitivity of degraded habitats to climate change.

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Appendices

Appendix 1. Invite to round 1.

Thank you for showing interest in taking part in a Natural England funded project investigating habitat sensitivity to climate change. The original assessment developed a H-M-L view of habitat sensitivity which still underpins much of our thinking around the climate vulnerability of the natural environment. However, the 3-point classification provides insufficient resolution to help prioritise interventions thorough mechanisms such as AES.

The Countryside and Community Research Institute (CCRI) is using a Delphi approach to develop a robust 1-5 sensitivity ranking, by developing a consensus expert view. The ultimate goal being to produce a pragmatic tool that can help inform delivery. Experts include specialists from NE, NRW and NatureScot, external practitioners and academics.

There will be two rounds of engagement (via email/online comments) over the next couple of months with a total time commitment around 3-4 hours. The process requires expert judgement rather than any additional research, hence will not be too time consuming.

Attached you will find:

1. A participant information sheet and consent form, highlighting the anonymous nature of this exercise; the consent form will need to be signed and returned with the 2 data collection files (excel sheets).
2. A task guide providing additional details and clarifications, including on the assumptions and definitions being used in this exercise. Please read this brief document before starting the task.
3. An excel file with the habitats listed where an assessment should be made on the basis the habitats are in **GOOD** condition (this is to done by adding an X to the appropriate column).
4. An excel file with the habitats listed where an assessment should be made on the basis the habitats are in **DEGRADED** condition (this is to done by adding an X to the appropriate column).

In this first (and main) round you are asked to fill in your assessment for habitat sensitivity to climate change in the 2 excel files (one for habitats in good condition and one for habitats in degraded condition). Brief justifications of your habitat assessment can be provided in the appropriate column in the excel files. These should then be returned with the signed consent form to Phil Staddon pstaddon@glos.ac.uk. Should you have any literature, especially grey literature, you feel of particular relevance, please forward to pstaddon@glos.ac.uk or deposit in a drop box folder or similar, the details of which we will provide shortly.

Please return your assessment within 2 weeks, by 14th February.

Appendix 2. Participant information sheet and consent form.

Participant Information Sheet and Consent Form

About the research

We (the CCRI) have been commissioned by Natural England to produce a rigorous and expert assessment of the sensitivity of habitats in England to climate change on a 5-point scale. This will allow better prioritisation of habitat protection needs.

Climate change is having ever greater impacts on natural ecosystems. Climate change and biodiversity loss are now commonly labelled as environmental emergencies. In this context, consideration of the differential impact of climate change on habitats is important to help prioritise our interventions if we are to protect our remaining natural environment, minimise biodiversity loss and maximise resilience to environmental changes including climate change. It is clear that not all habitats are the same in terms of their sensitivity to a changing climate, some, such as lowland calcareous grassland, appear to be relatively resilient, whilst others such as montane habitats are more sensitive to elements of a changing climate, in this case warming.

Natural England's understanding of these issues was first articulated in the England Biodiversity strategy, (Mitchell et al. 2007), which grouped habitats on a three-point scale as being at High, Medium or Low sensitivity. This hierarchy has been used in NE's climate change vulnerability modelling (Taylor et al. 2014) and NE's approach to adaptation (Natural England and RSPB 2019). The vulnerability model offers a way to operationalise this understanding, but the High-Medium-Low hierarchy and limited number of habitats considered limits the resolution that researcher and policy makers are able to work with. For this reason, preliminary work was recently undertaken by NE specialists to expand the scale into a 1-5 score and include more habitats.

Natural England want to take this preliminary work to the next level and incorporate the latest evidence and expert opinion into a 5-point scale on the sensitivity of habitats to climate change. In addition to this, the degree of habitat degradation should be considered when assessing the sensitivity of habitats to climate change. Broadly speaking a degraded habitat is likely to be more adversely impacted than a habitat in good condition, primarily because of a loss of resistance and resilience to environmental perturbations. This impact of the level of degradation on the sensitivity to external perturbations will vary across habitats. For example, a hydrologically intact functioning lowland raised bog is relatively resilient to climate change, whilst one where the hydrology is compromised is likely to be highly sensitive; conversely the sensitivity of calcareous grassland is less likely to change as significantly whether it is in good condition or not (depending on the outcome measure assessed).

Before you decide whether to take part, it is important you understand why the research is being done and what it will involve. Please take time to read the following FAQs and then decide whether you want to take part. You will be able to give your consent on the next page.

Why am I being asked to participate?

We are seeking the input of experts in this field.

What are the possible benefits of participation?

This commission offers a unique opportunity to input into the assessment of the sensitivity of habitats in England to climate change on a 5-point scale.

What do I need to do?

We will ask you to participate in Round 1, where you will be asked to assign scores on a 5 point scale to habitat sensitivity to climate change , before participating in Round 2 which will allow working and inputting comments to the consolidated outputs from round 1. Round 2 will be anonymous.

Do I have to take part in both rounds?

No. If you wanted to just take part in one or the other, do let us know.

Do I have to take part?

No. It is entirely up to you whether you decide to participate.

Who has reviewed this research for ethical clearance?

The Delphi survey has been approved by the University of Gloucestershire Ethics Committee and steps have been taken to ensure the survey (and the wider research) fully complies with the necessary personal data management procedures in place at the University (more info can be found here: https://www.glos.ac.uk/research/research-ethics/).

Will I remain anonymous if I take part? Will my responses be held confidentially?

Round 1 Delphi responses (emailed task) will be anonymised before being reported back to Natural England, with any (direct or indirect) identifiable details removed or reduced. Aggregate findings from Round 1 will be presented as part of Round 2, but NOT linked to your name. By participating in Round 2, you will remain unknown to other participants working on the shared document. You will not be required to answer any questions you are uncomfortable about.

To participate in the task you will have to enter your name and email address; we will use these details to contact you about the delphi rounds and survey results. These details will be deleted at the end of the project (March 2022). These details will not be linked with any results in any reporting. Personal data will be held both securely (on the University's OneDrive) and confidentially in line with our GDPR requirements.

Withdrawal

Having participated in the survey you will have 30 days to withdraw your response. You can withdraw by emailing pstaddon@glos.ac.uk. You can also request to see your task data (i.e. the document you will have completed and sent to pstaddon@glos.ac.uk) at any time up until the end of the project (March 31st 2022).

Although we are bound by confidentiality, we may be required to disclose confidential information regarding their participants to the appropriate authorities when required by law or if there is a special duty to report.

What if I have any questions?

Please email the research team (pstaddon@glos.ac.uk) or phone 01242 715314.

Round 1 (emailed task) Consent Form

- I confirm I am aged 18 or over
- I feel I have received enough information about this research (via the Participant Information Sheet)
- I understand that my participation in this Delphi survey is voluntary and that I can withdraw up to 30 days after participating without having to give a reason
- I understand my responses will be anonymised in any reporting
- I understand the CCRI research team has access to my non-anonymised survey responses
- I know who to ask if I have any further questions
- I am happy to participate in the survey

Date: …………………………………………...

Signature: ……………………………………..

Name: ………………………………………….

Appendix 3. Task guide round 1.

Habitat sensitivity to climate change

Natural England funded research delivered in partnership with the Countryside and Community Research Institute (CCRI)

Document prepared 28.01.22

This consultation aims to come to an expert-led consensus on the understanding of the sensitivity of UK habitats to climate change. The objective being to produce a pragmatic assessment that will be used to support the prioritisation of interventions to promote adaptation to climate change.

The sensitivity of habitats to climate change should be considered for a) good habitats and b) degraded habitats.

There will be two rounds of consultations:

1. Initial individual response from experts (anonymous)
2. Feedback on the consolidated results (anonymous joint working in a shared document)

Habitats. The focus will be on the terrestrial and coastal JNCC UK BAP Priority Habitats. Marine habitats are not part of the assessment. A different typology has been used for rivers, and some of Priority Habitats have been subdivided [see *Appendix 1*]. You will have the opportunity to provide information on your knowledge of the habitat (e.g. limited, average, extensive), which will be factored into the consensus view.

Climate change. The analysis with regards sensitivity to climate change should focus on the results from the UK Climate Projections 2018 (UKCP18), updated 2021: (https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18_headline_findings_v3.pdf). The key projections are: continued warming of all areas; greater warming in the summer than the winter; more frequent hot summers (with heatwaves); hot summers becoming more widespread away from the South East; likely significant decrease in precipitation the summer, but an increase in the winter; an increase in rainfall intensity. The rise in extreme weather events and sea-level rise should be factored in, as should the increased within and between year variance. Indirect risks (wildfires, pests, diseases, invasives, changes in abstraction, changes in the ability to manage that habitat) should be considered.

Definitions. Terms used are defined here as their use within the scope of this consultation. Other definitions exist.

- **Sensitivity**: the outcome of the inherent sensitivity and adaptative capacity of the habitat to environmental changes.
- **Vulnerability**: the degree to which a habitat is susceptible to environmental perturbation (climate change) in its ability to resist or recover from perturbations that it is exposed to;

- **Exposure**: the level of environmental (climate change) perturbation a habitat will experience
- **Degradation**: the current state of the habitat in terms of ecological composition and functioning. Degradation is likely to affect resilience of habitats but in theory does not affect the inherent sensitivity of habitat to external perturbations.

Habitat status. A **good habitat** is one where it contains all or most of the key organisms expected in that habitat type and where it is functioning similarly or close to a pristine habitat, and therefore can be considered to be in a favourable condition or conservation status. A **degraded habitat** is one which is still recognisable as of that habitat type but is lacking some key element/species/ association; the aim of this consultation is to understand how the average status of the habitat might impacts its sensitivity to climate change. Please refer to *Appendix 2* for a summary of degradation pressures.

For the purpose of this assessment, consider the sensitivity **over a period of 30 yrs**.

QUESTIONS

1. Assuming a **good habitat status for these priority habitats** across the UK, please score on a scale of 1 to 5 their sensitivity to climate change, where 1 = low sensitivity, 3 = mid sensitivity, 5 = high sensitivity.

2. Based on your understanding of **the average state of these priority habitats** across the UK (i.e. degraded to a certain extent), please score on a scale of 1 to 5 their sensitivity to climate change, where 1 = low sensitivity, 3 = mid sensitivity, 5 = high sensitivity.

Please submit or highlight any key evidence that supports your assessment, including that from the published and grey literature.

Appendix 4. Invite and task guide round 2.

Thank you for your input to round 1, the results were fascinating and we are very grateful for your timeliness in turning this round so quickly. Here in round 2 we are asking you to look at the consolidated scores for each habitat with a critical eye. As with round 1, this round is again anonymous.

The overall pattern aligns well with the evidence base on impacts, however there are a few instances in some habitats where this may not be the case. For the second round in particular, please check whether there are any questions arising around the sensitivity score within broad habitat types; but, also if relative sensitivity of broad habitat types is justified. At this stage we are particularly interested in identifying any discrepancies between habitats with regard to the scoring and your understanding of the evidence base, or any apparent discrepancies between the consolidated score and the justifications. Where this might be the case please highlight whether the scoring should be altered and by how much it should change.

Please find attached two consolidated versions of habitat sensitivity scores to climate change; one for habitats of GOOD status, and one for habitats of DEGRADED status.

You will see:

- The consolidated expert weighted score for each habitat on a 5-point scale
- The very brief justification summary based on key words
- A link to the justification received for each habitat (**column L**)
- A series of columns (M to AG) organising the justification for each respondent allow you to see how each respondent replied across habitat

Please add any comments on perceived incorrect final score or discrepancies in column J.
We do not envisage that this task will take as long as Round 1, so please return your excel files by email to (pstaddon@glos.ac.uk) before 6 pm on Monday 7th March.

www.gov.uk/natural-england